controlling bus **130**. An interrupt controller **135** is used for receiving and processing various interrupt signals from the system components.

[**0035**] Mass storage of data may be provided by a diskette, CD ROM **147**, or hard drive **152**. Data and software may be exchanged with computer system **100** via removable media **147** such as diskette of CD ROM. Removable media **147** is insertable into drive **146** that is, in turn, connected to bus **130** by a controller **145**. Hard disk **152** is part of a fixed disk drive **151** that is connected to bus **130** by controller **150**.

[**0036**] User input to computer system **100** may be provided by a number of devices. For example, a keyboard **156** and mouse **157** are connected to bus **130** by controller **155**. Similarly, an image input device **141**, such as a scanner, is connected to bus **130** by controller **140**. An optional audio transducer **196**, which may act as both a microphone and a speaker, is connected to bus **130** by audio controller **197**, as illustrated. It will be obvious to those skilled in the art that other input devices, such as a pen and/or tabloid may be connected to bus **130** and an appropriate controller and software, as required. Direct memory access (DMA) controller **160** is provided for performing direct memory access to RAM **110**. A visual display is generated by video controller **165** that controls video display **170**. Computer system **100** also includes a communications adaptor **190** that allows the system to be interconnected to a local area network (LAN) or a wide area network (WAN), schematically illustrated by bus **191** and network **195**.

[**0037**] Operation of computer system **100** is generally controlled and coordinated by operating system software, such as the OS/2® operating system, available from International Business Machines Corporation, Boca Raton, Fla. or Windows 95® from Microsoft Corp., Edmond, Wash. The operating system controls allocation of system resources and performs tasks such as processing scheduling, memory management, networking, and I/O services, among things. In particular, an operating system resident in system memory and running on CPU **105** coordinates the operation of the other elements of computer system **100**. The present invention may be implemented with any number of commercially available operating systems including OS/2, UNIX Windows NT and DOS, etc. One or more applications, such as Lotus Notes, commercially available from Lotus Development Corp., Cambridge, Mass., may be executable under the direction of the operating system. If the operating system is a true multitasking operating system, such as OS/2, multiple applications may execute simultaneously.

[**0038**] In a similar manner to **FIG. 2**, **FIG. 4** also shows the apparatus **100** of the present invention with its imaging device **102** aligned with the video display **170**. The tactile display device **104** receives information in the form of light from the imaging device **102** and provides a tactile image in accordance with the information. In this embodiment, the apparatus **100** is shown coupled to an external power supply **106**, such as an electrical outlet.

[**0039**] According to the invention, imaging means converts light received from the displayed visual image into electrical signals. An array of photometers of various types, such as photodiodes, may be used to form the imaging means. The tactile display means converts the electrical signals from the photometers into "tactile images" corresponding to the displayed visual image. Consequently, the tactile images can be perceived through the sense of touch by a person, such as a visually impaired person. Therefore, the tactile images are felt by the visually impaired person and enable them to interact with computers in a manner similar to how a sighted person would interact with graphical user interface. While the tactile display means is preferably of the same length and width dimensions as the image being processed, it is possible for the tactile display means to be scaled to a smaller or bigger size.

[**0040**] As shown in **FIGS. 5A and 5B**, the tactile display **104** may be secured at a narrow gap from the surface of the touch screen **170** so that touching or pressing the individual pins **200** in the tactile display conveys or transmits a similar touching or pressing upon the touch screen **170**. By positioning the imaging means or photometer in or near the end **202** of the pins **200**, the imaging/tactile device forms a true and complete interface, i.e., both input and output, between the touch screen **170** of the computing device and the operator's finger **204**. The interaction between the tactile display and the touch screen display relies upon the user's touch input and does not require any direct electronic attachments or communications with the computing device. **FIG. 5B** illustrates that pressing the finger **204** against the pins **200** in a region **206** of the tactile display **104** will cause the pins to touch the touch screen **170** in a region **208** that is directly behind the region **206**.

[**0041**] The tactile display means may comprise a plurality of individually controlled miniature actuators, a plurality of miniature gear assemblies, and a plurality of rods. The miniature actuators, e.g., motors, piezoelectric materials, shape memory elements or solenoids, are oriented in a grid, wherein each of the motors or solenoids responds to a portion of the processed electrical signals. Apparatus using shape memory elements to for a tactile display are described in U.S. Pat. No. 5,244,288, which patent is incorporated by reference herein.

[**0042**] FIGS. **6**A-C are side views of a miniature actuator assembly **210** in accordance with one embodiment comprising a rack **212** and pinion gear **214** assembly operatively connected to a rod **216** so that rotational motion of a pinion gear **214** connected to a shaft of a miniature actuator motor **218** is converted into linear motion of a rack. The rod **216** is connected to the rack **212** so that when the rack moves linearly, the rods move linearly as well. A tactile image is thus formed by incorporating an array of such miniature actuator assemblies **210**. A similar rack and pinion actuator is described in U.S. Pat. No. 5,636,038, which patent is incorporated by reference herein.

[**0043**] In **FIG. 6**A, the rod or pin **216** is in the downward position as dictated by a control signal **220** that is directly or indirectly provided by the photometer **222** facing the touch screen **170**. The photometer **222** is preferably formed in the end of the actuator assembly **210** and provides a signal representing the gray scale light intensity, or luminescence, to a controller that then forwards the control signal **220** to the motor **220**. In **FIG. 6**B, the rod or pin **216** has been extended above the tactile display surface **224**. In **FIG. 6**C, the rod or pin **216** is shown being depressed by a user in order to make a touch selection from the display. With the motor **218** held in position by the control signal **220** the actuator has a greater length than in **FIG. 6A**. Pressing upon